

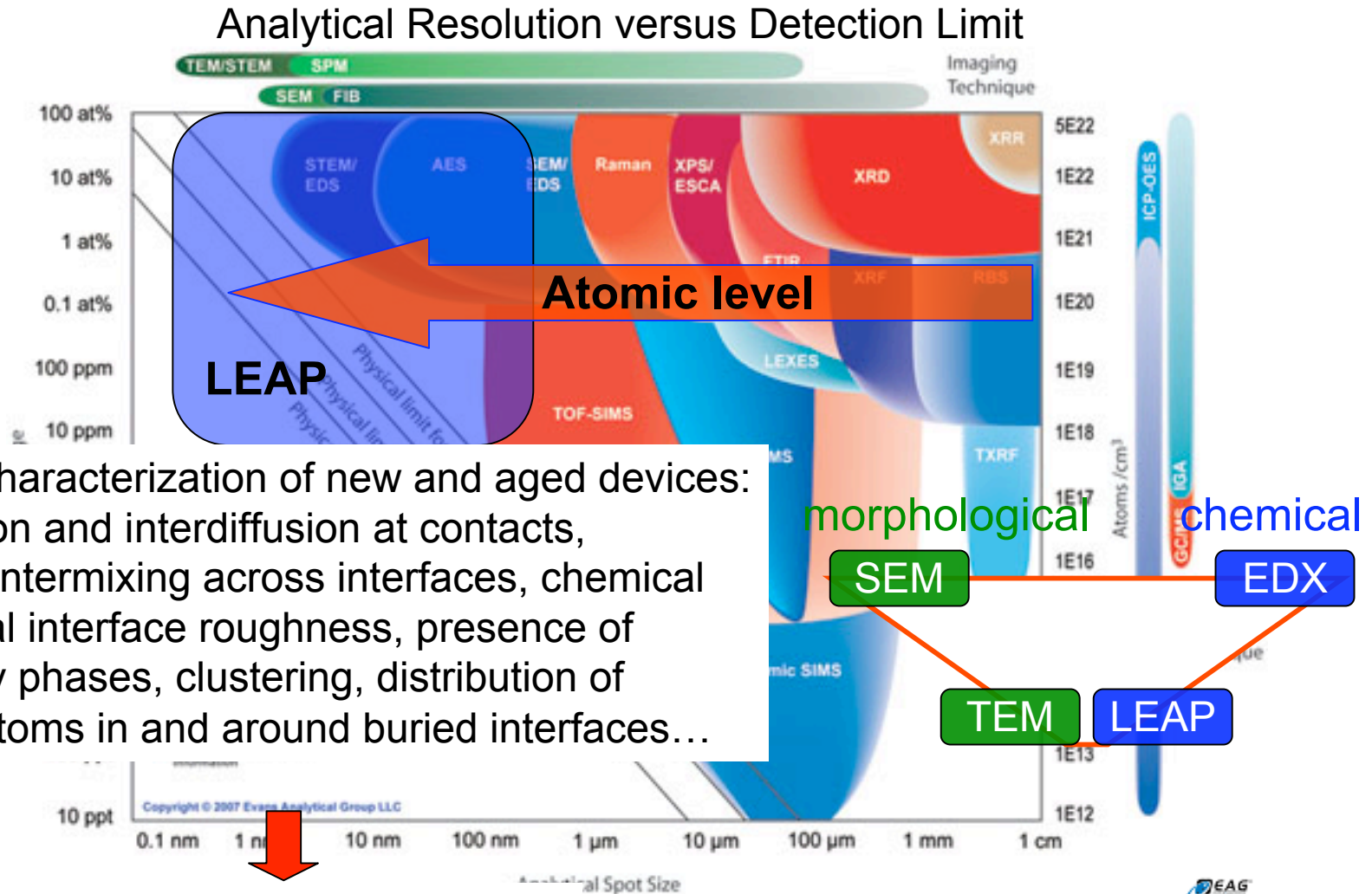
A 21<sup>st</sup> Century approach to Electronic Device  
Reliability  
MURI Kick-off meeting

Materials characterization: LEAP

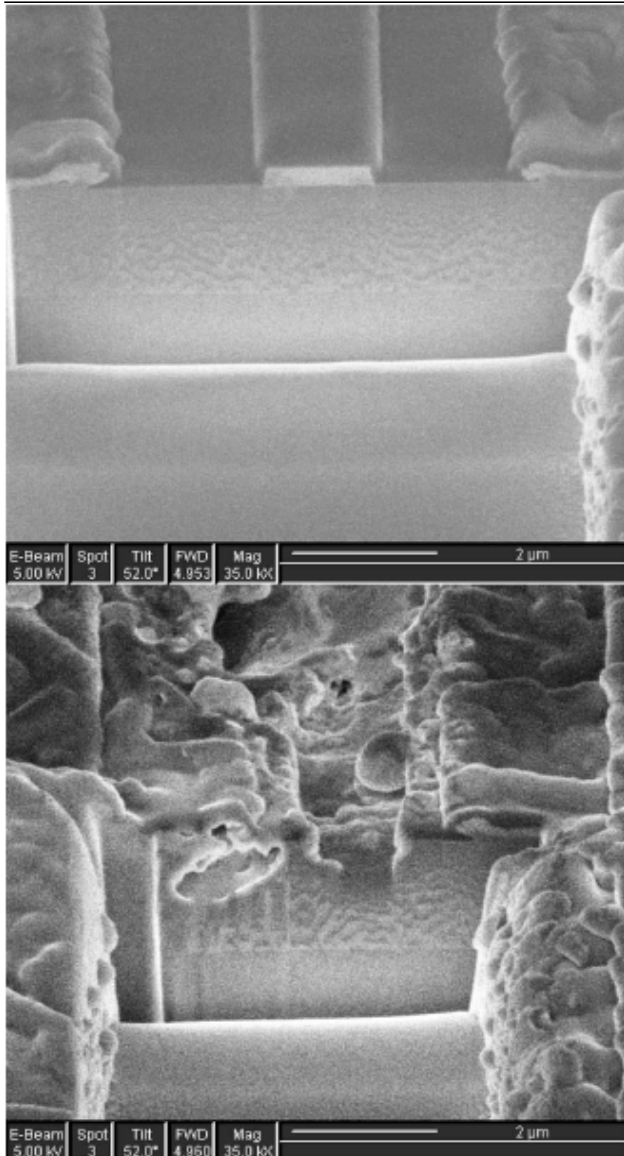
Lucia Romano, Kevin S. Jones



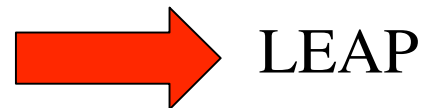
# Atomic level resolution



# GaN



- Needs for stable ohmic contacts
- Long term stability during high temperature operation
  - ⇒ Metal layers begin to intermix
  - ⇒ Formation of different phases ( $\text{AlAu}_4$ )



AlGaN/GaN HEMTs with conventional contacts before and after aging to failure.

R. Khanna Et Al., Ieee Transactions On Device And Materials Reliability, 8 (2008) 272

# Outline

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- LEAP
  - What is a LEAP?
  - Characteristics
  - Sample preparation
- Examples:
  - Si/SiGe
  - As implanted Si/polySi
  - SOFC



# What is LEAP?

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## Local Electrode Atom Probe

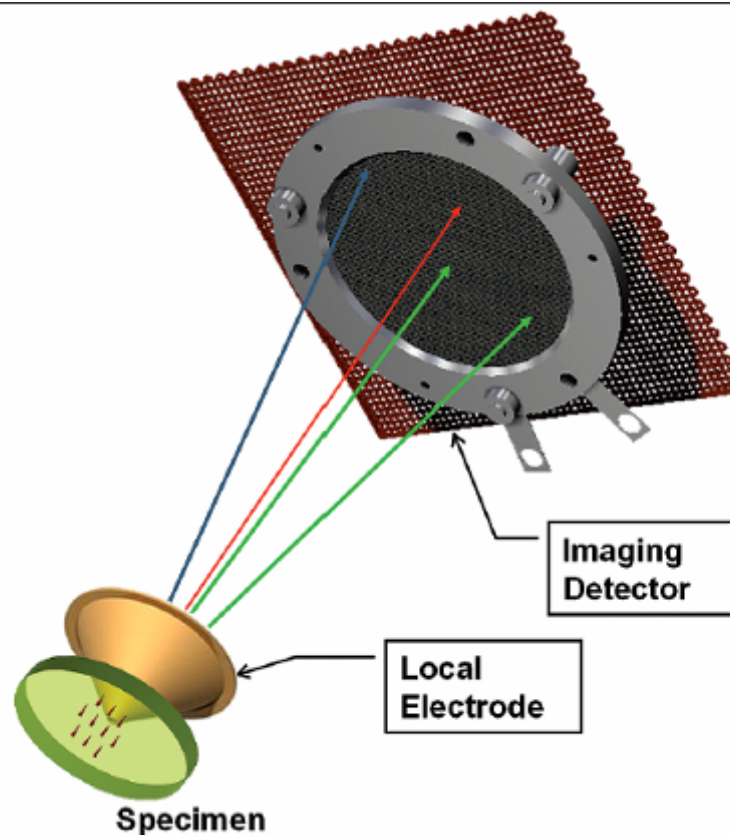
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LEAP at University of  
North Texas, Denton

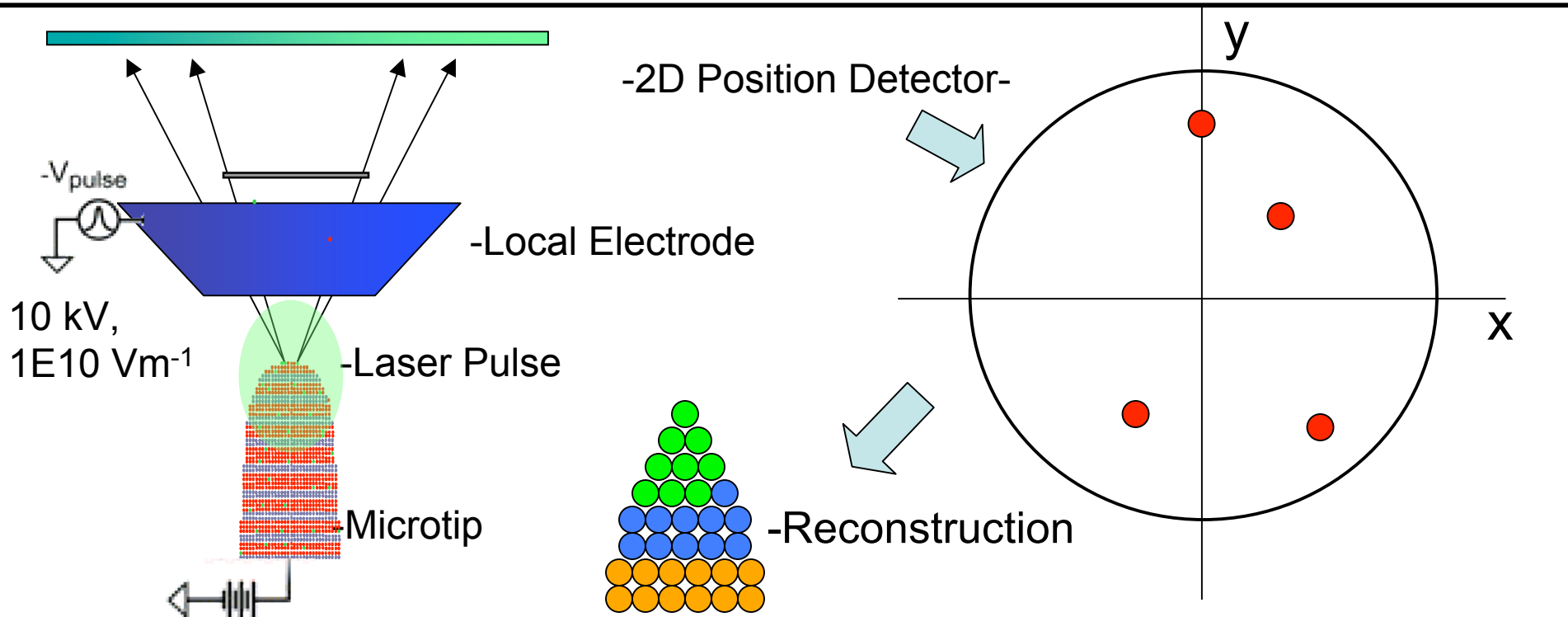
LEAP at University of  
Alabama, Tuscaloosa

LEAP at IBM Fishkill, NY

...soon at UF



# Local Electrode Atom Probe



Raw data:

- Position (x,y) of impact on the detector
- Sequence number
- Time of flight

reconstruction

Information:

- Position of the atom in the (x,y) plane of the tip
- Position along the z axis
- Chemical identity

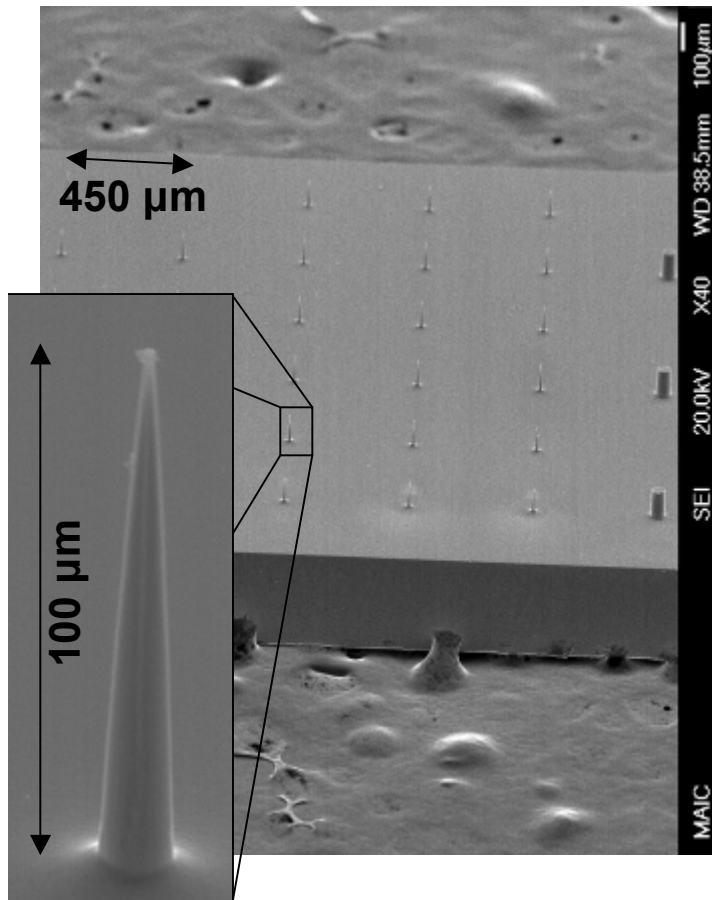
# LEAP characteristics

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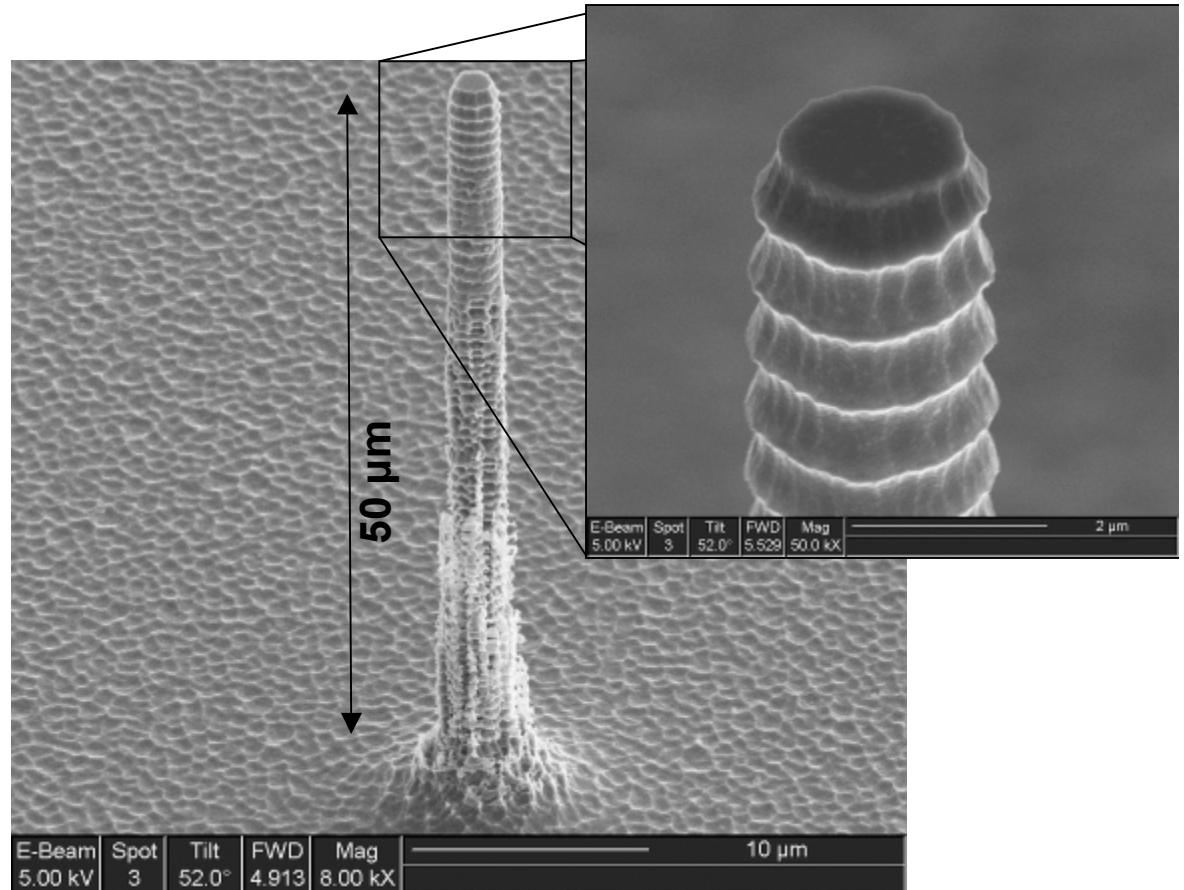
- 3D quantitative compositional imaging and analysis
- All elements detectable (+ isotopes) with equal efficiency and without need for a priori knowledge of the composition
- Spatial Resolution 0.4nm laterally and <0.2 nm depth
- High analytical sensitivity:10 ppm
- Field of view ~100 nm, 20million ions for standard dataset
- ultra-fast pulsed laser 250 kHz (36 million atoms  $\text{h}^{-1}$ ) for semiconductors and insulators
- High detection efficiency (>50%)
- 750:1 FWHM mass-to-charge resolution

# LEAP post array

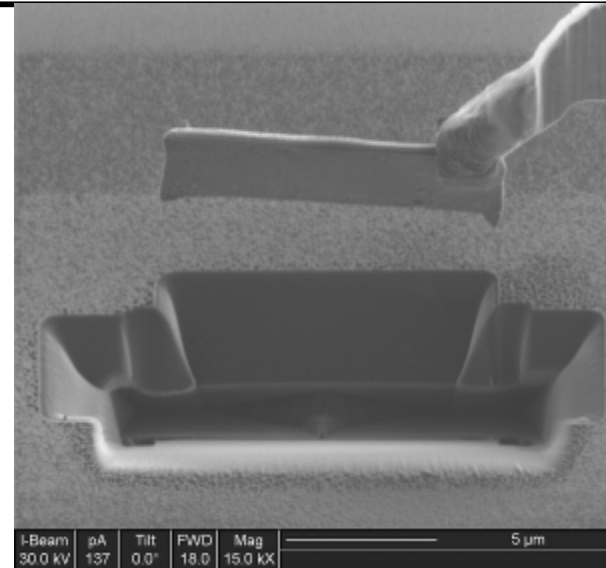
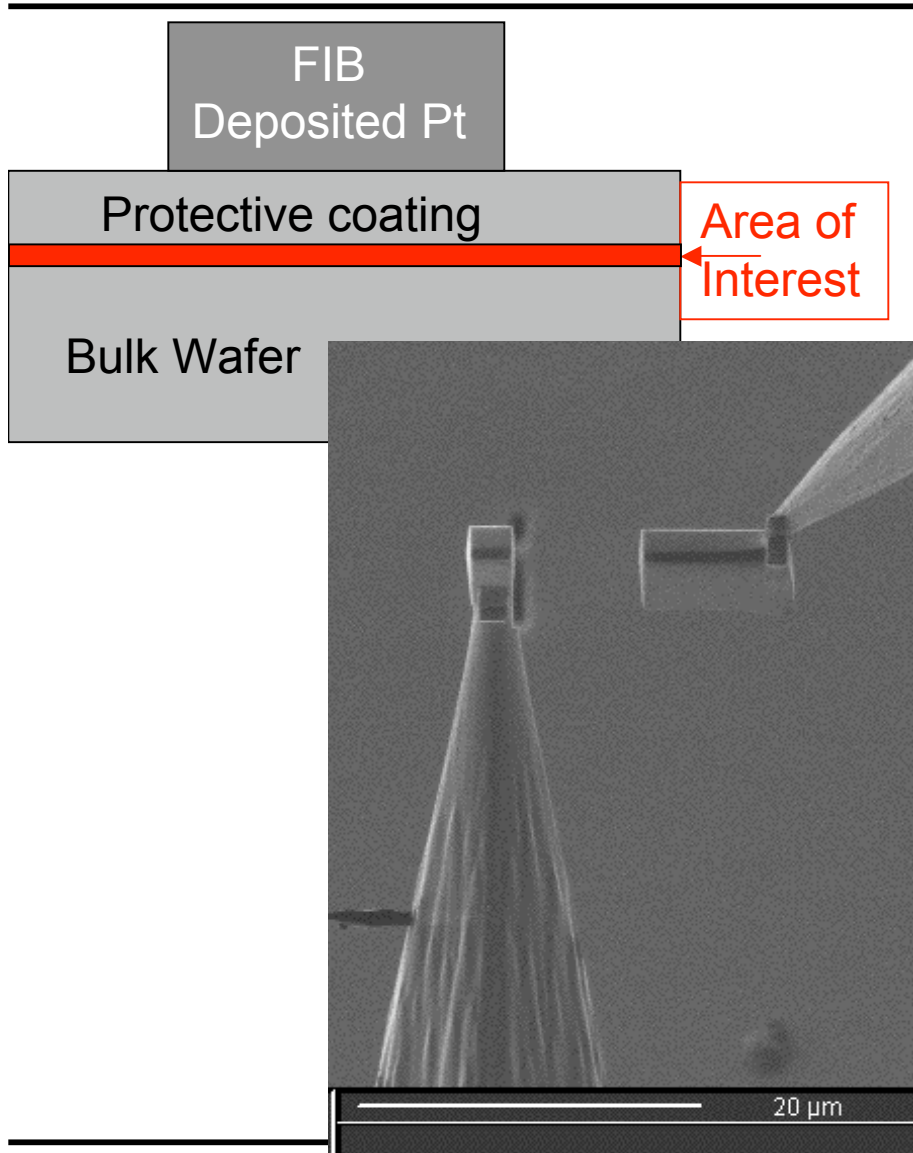
by IMAGO



DRIE post at UF



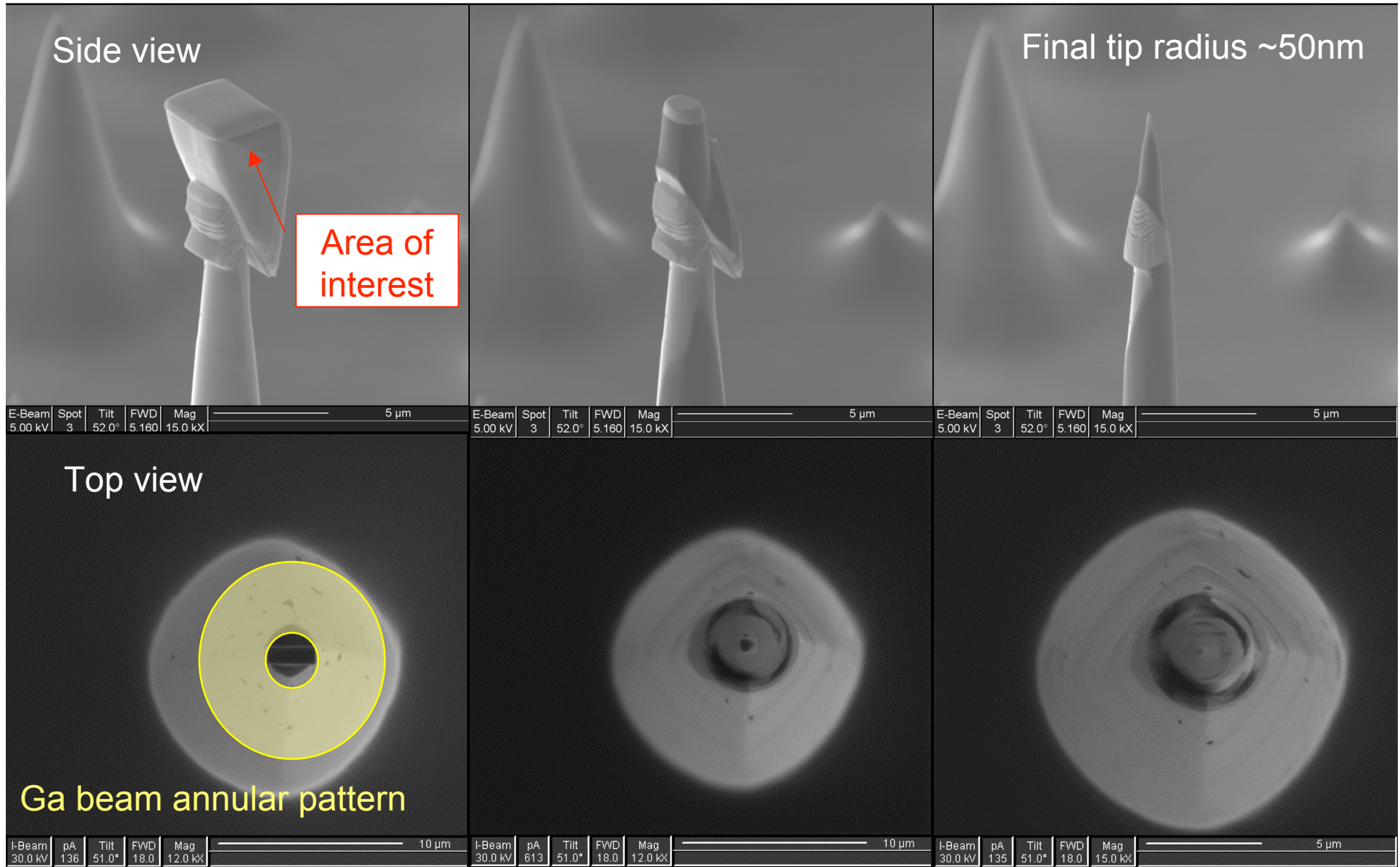
# FIB Liftout



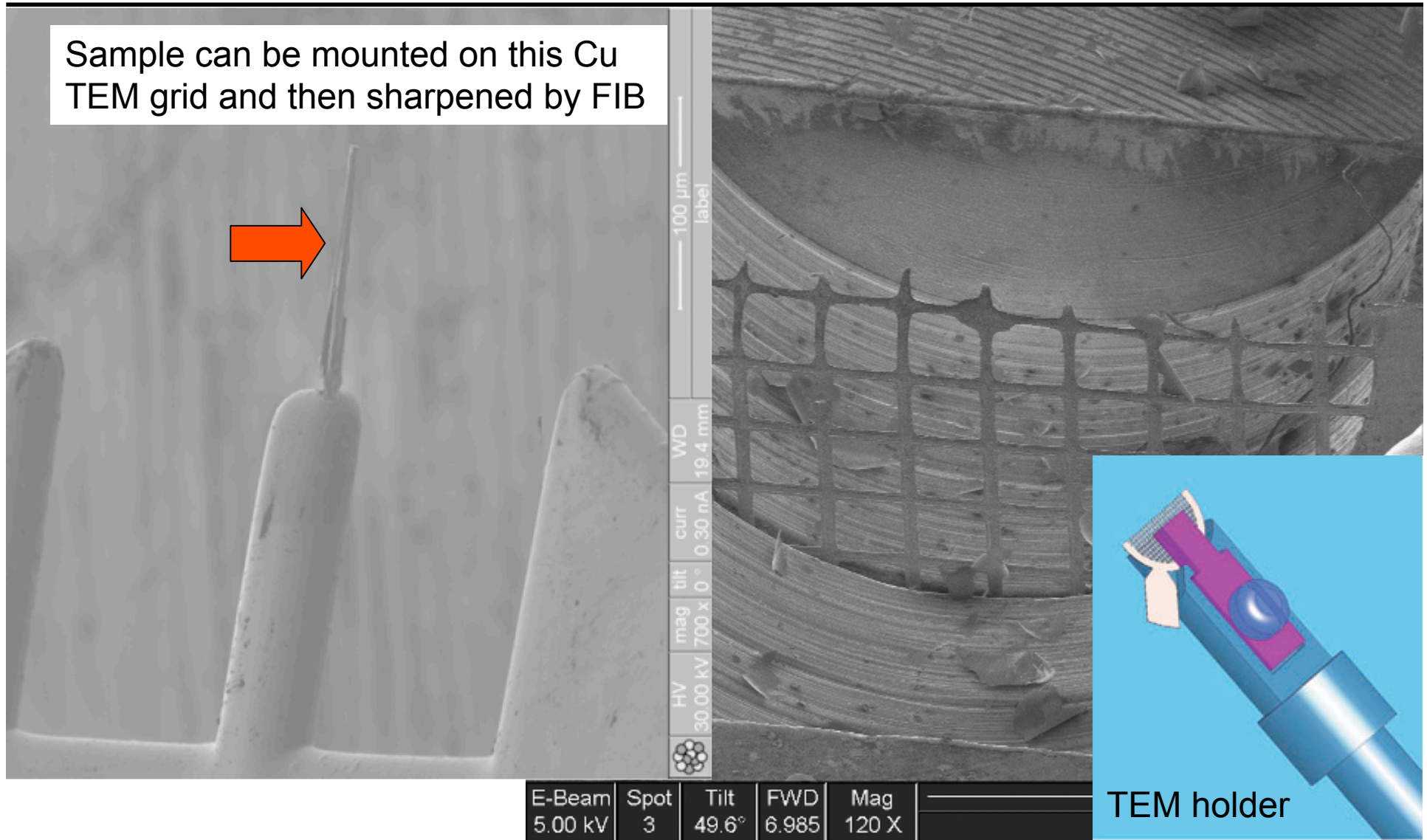
- 1) FIB milling surrounding the protective coating
- 2) undercut
- 3) Cut free
- 4) Lifted out by omniprobe
- 5) Mounted on a post



# FIB tip sharpening



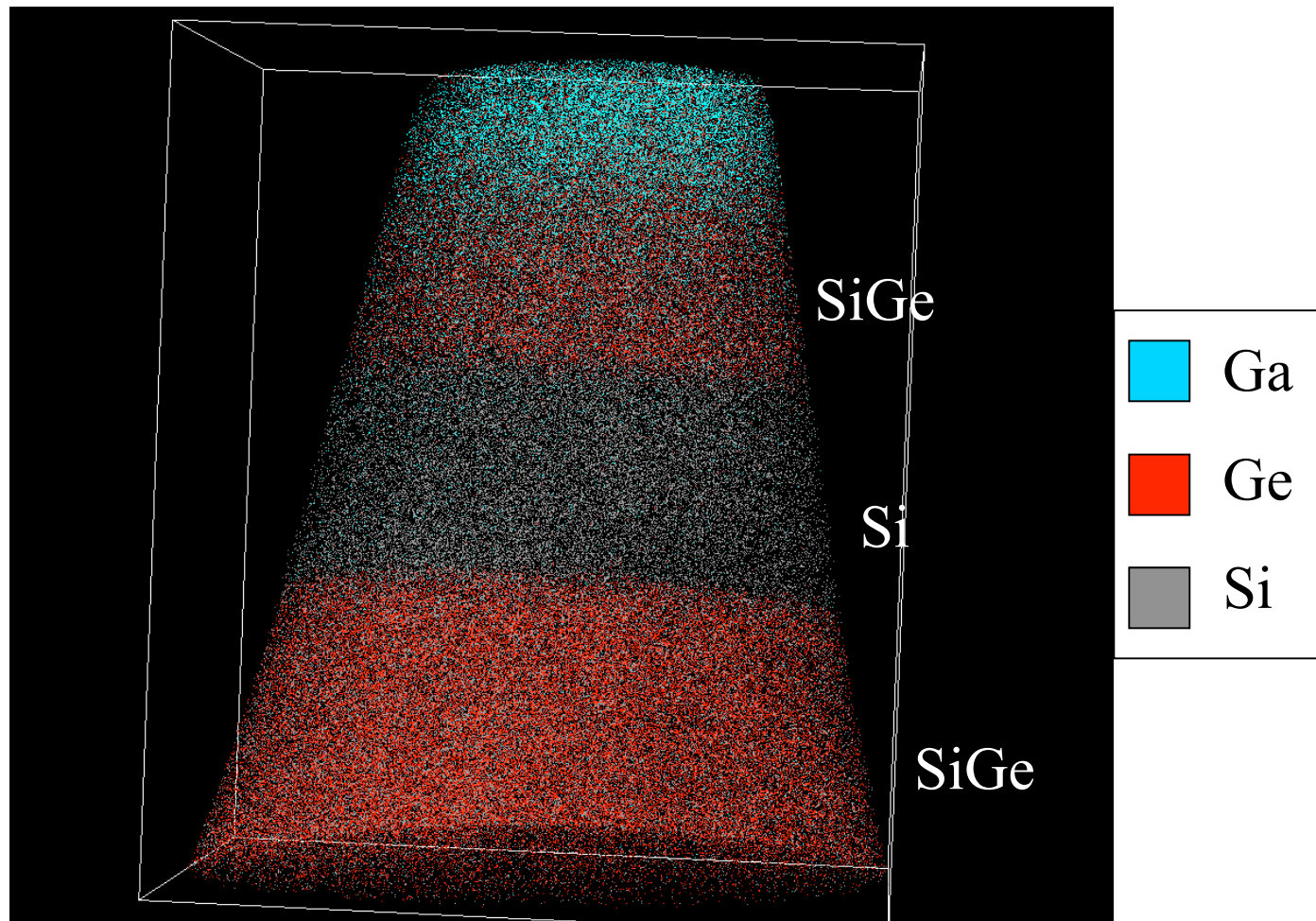
# LEAP-TEM on the same tip



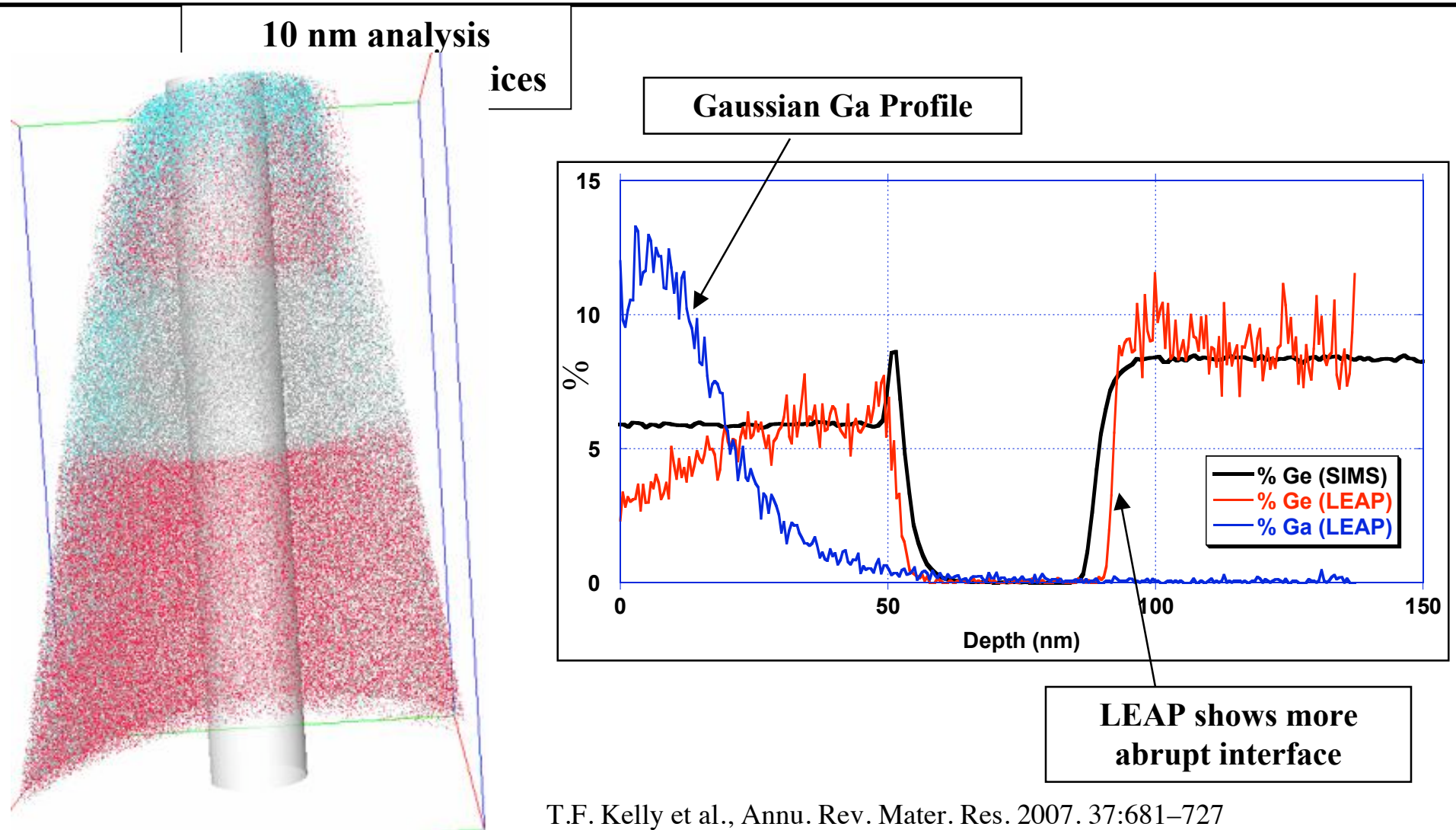


# 1 Example Si/SiGe Stack

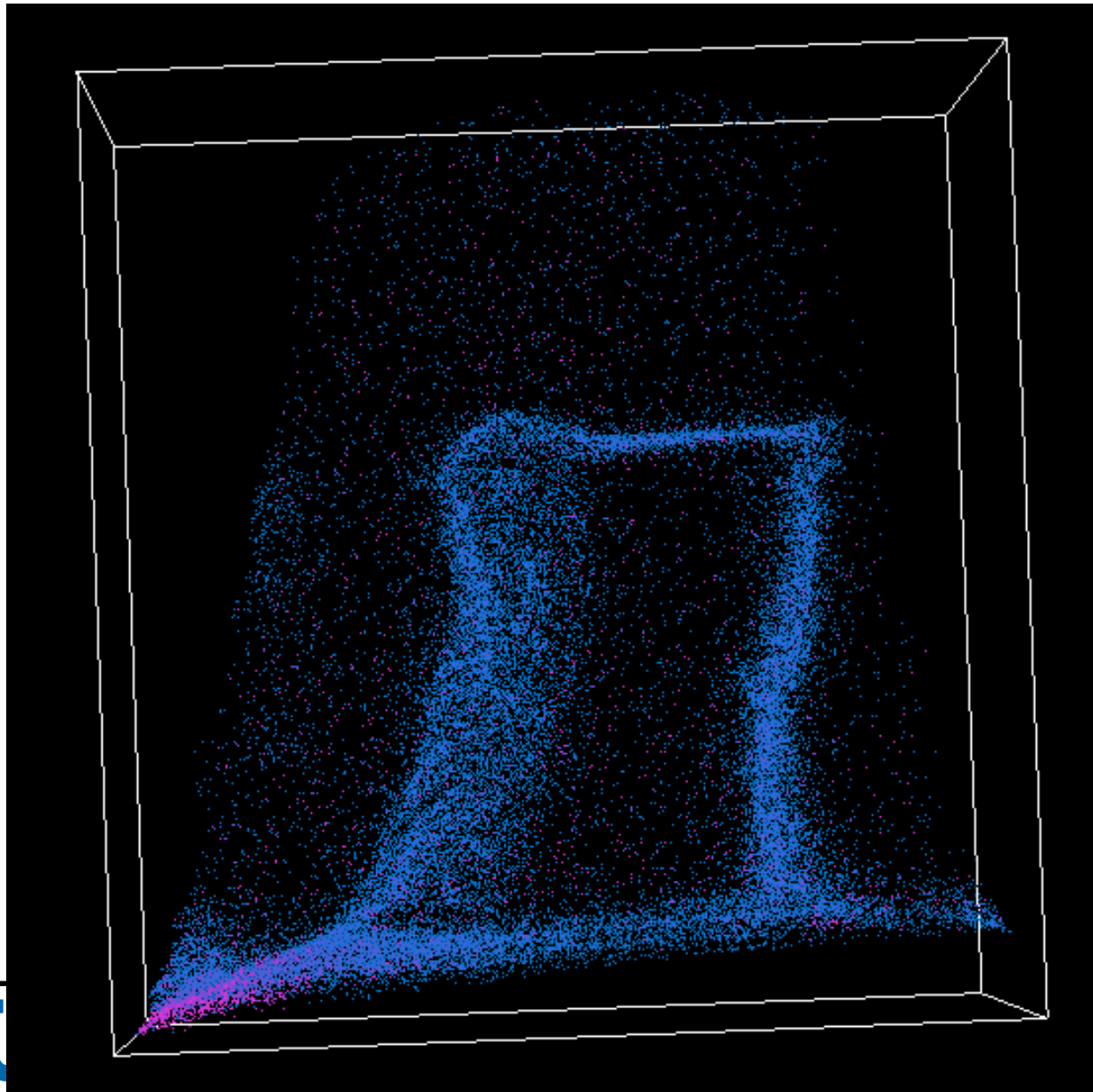
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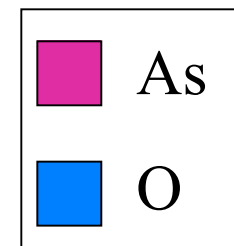
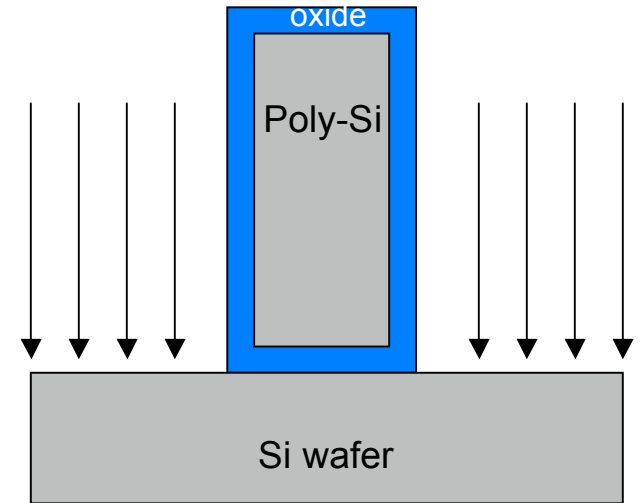
# Si/SiGe Stack



## 2 Example: As implanted Si

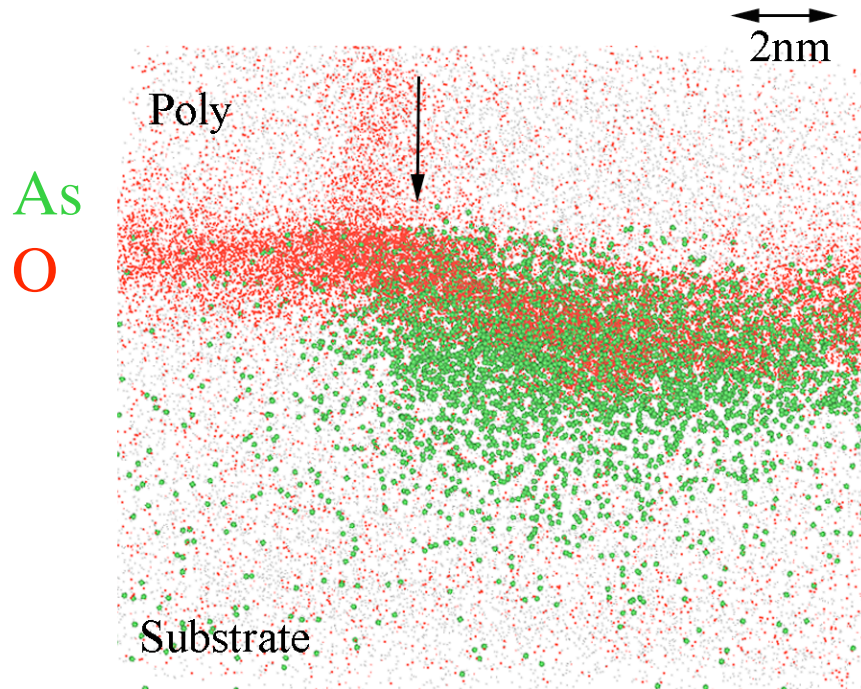


3keV  $1E15/cm^2$  As<sup>+</sup> Implant  
Annealed 950°C Spike



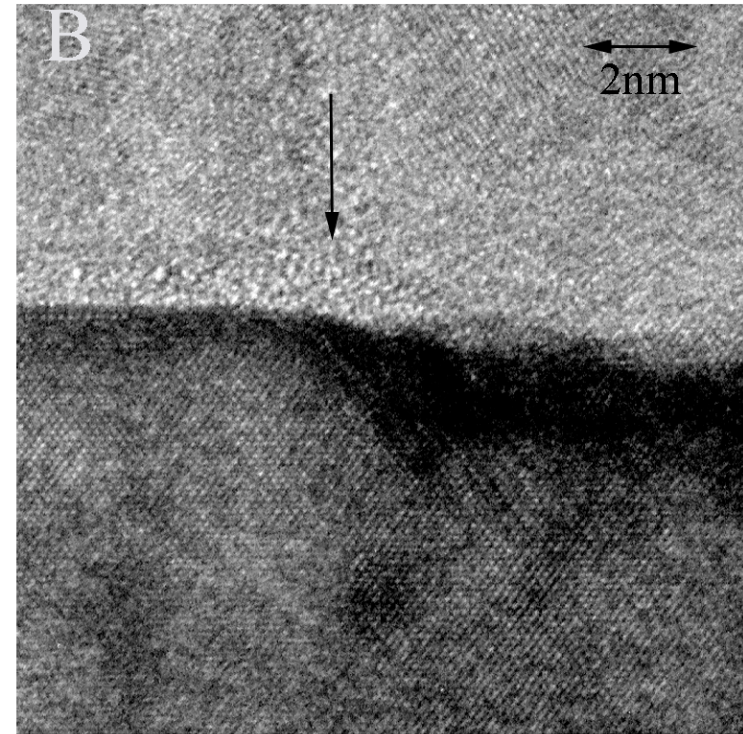


# LEAP-XTEM



LEAP

- 3 keV  $1 \times 10^{15}$  As<sup>+</sup> implant
- Annealed at 950°C in Intel Process Line

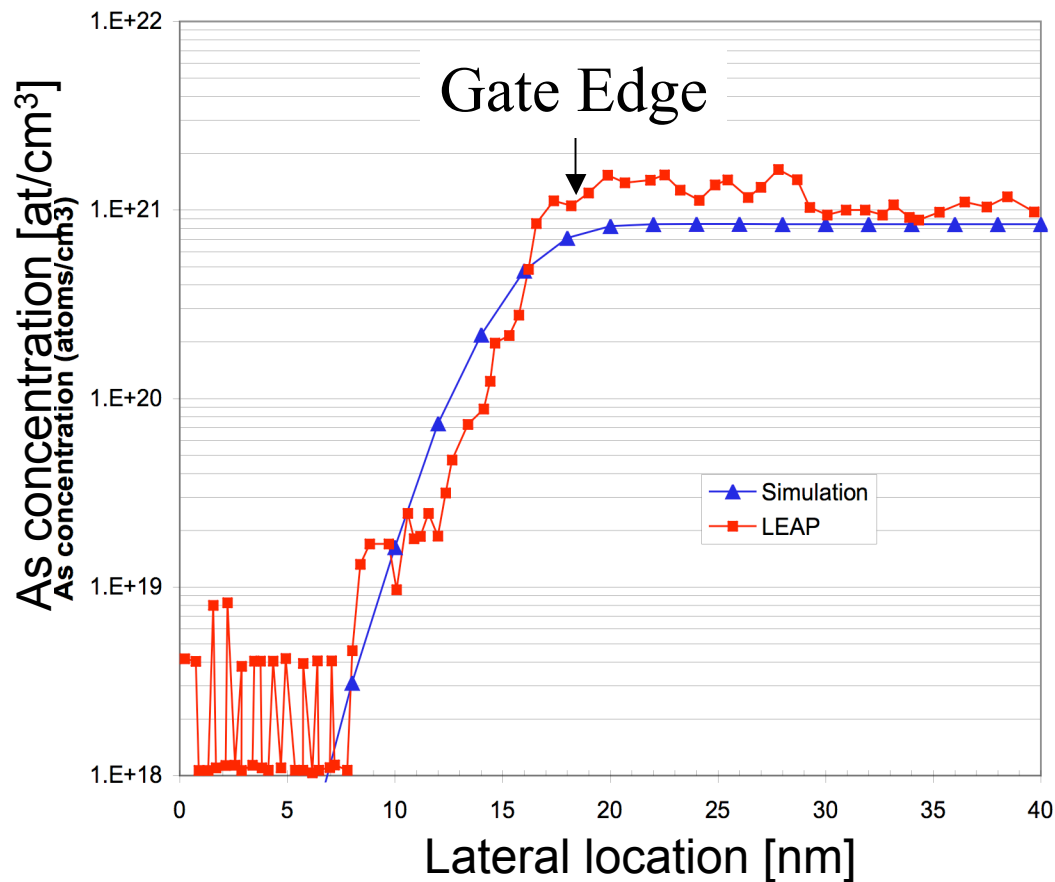


HRTEM

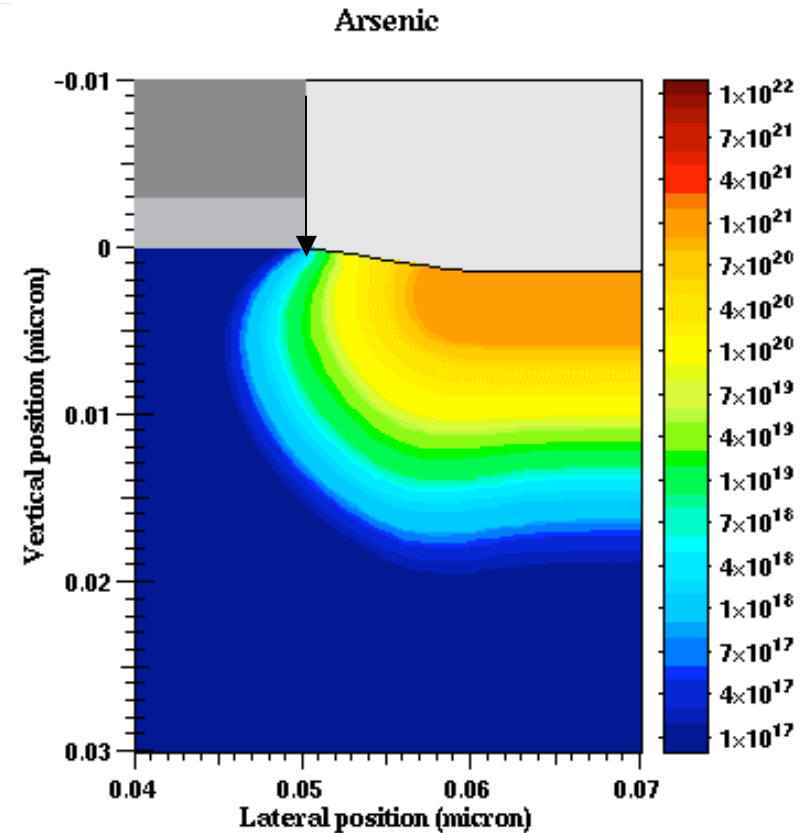
J.S. Moore et al., Ultramicroscopy 108 (2008) 536–539

# LEAP-FLOOPS

## LEAP



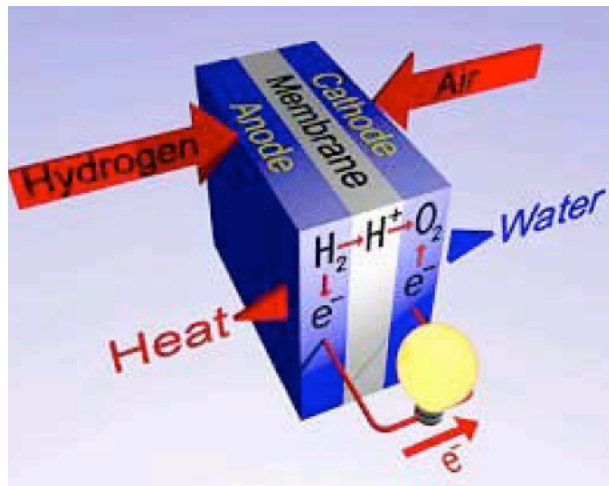
## FLOOPS



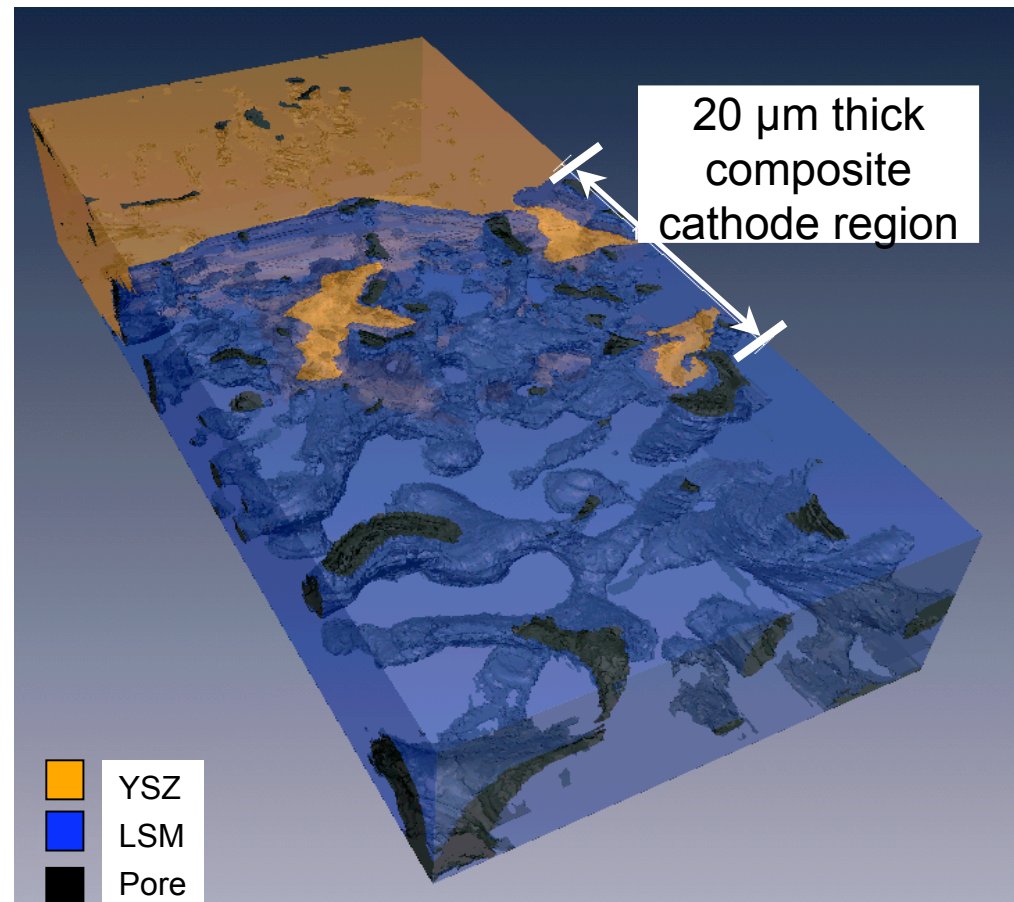
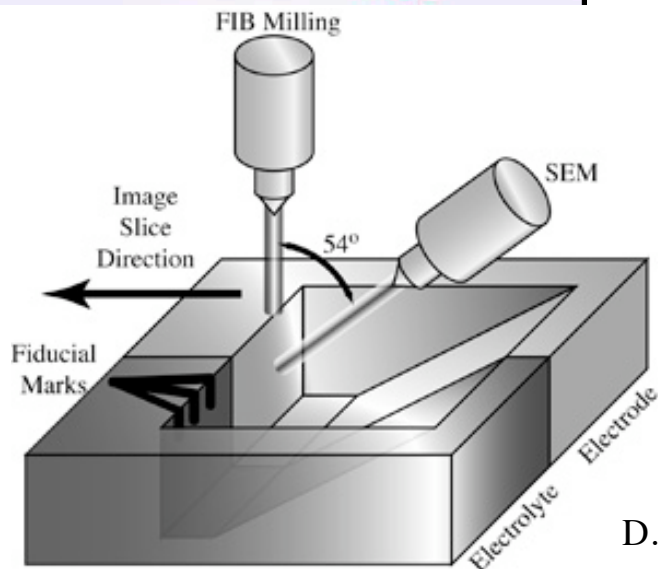
J.S. Moore et al., Ultramicroscopy 108 (2008) 536–539

### 3 Example: SOFC

#### Micro-structural characterization by FIB-SEM



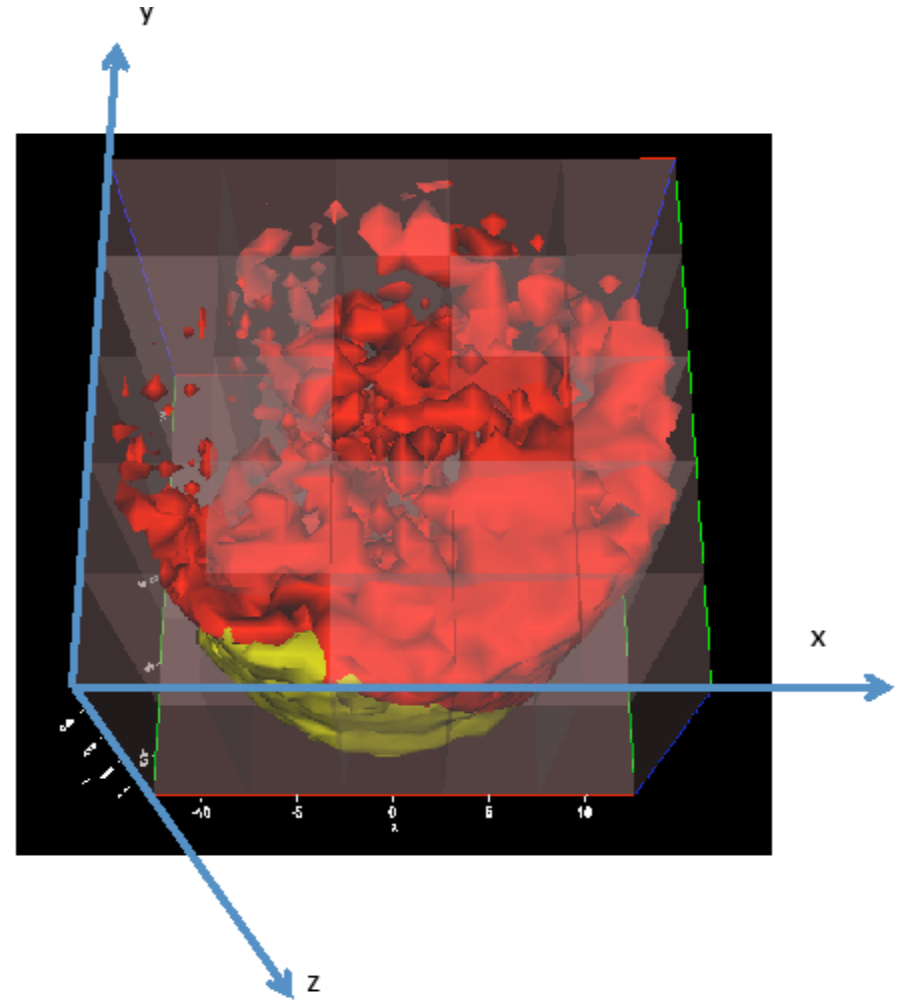
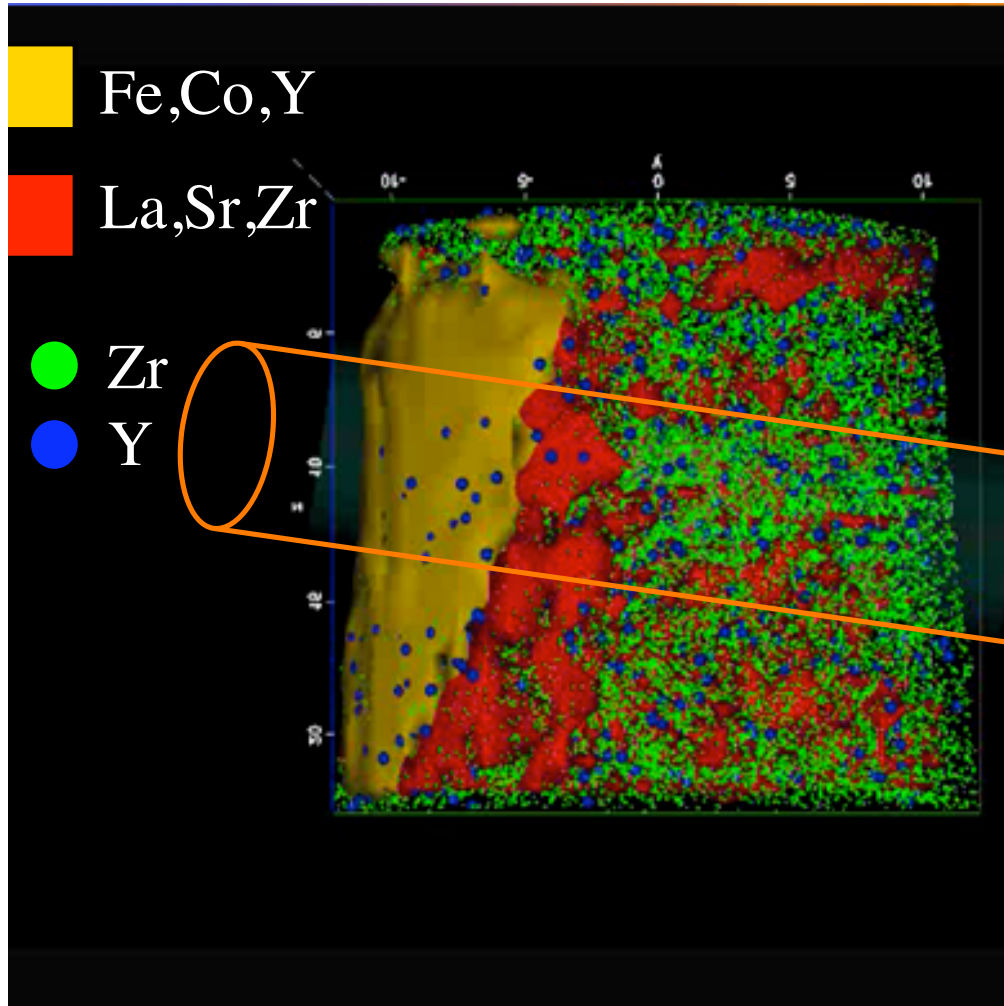
Solid  
Oxide  
Fuel  
Cells

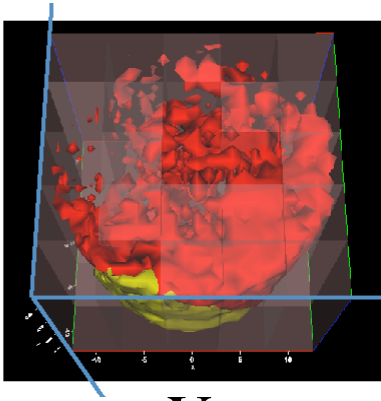


D. Gostovic et al., Electrochemical and Solid-State Letters, **10** 12 B214-B217 2007



# LEAP study





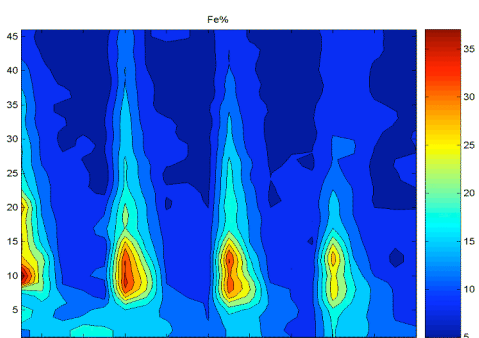
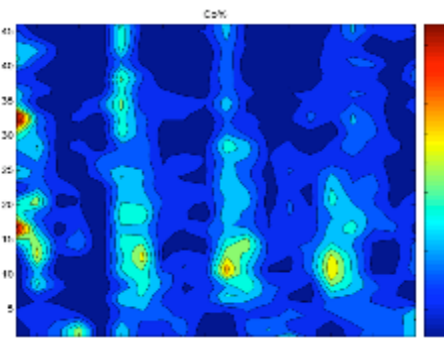
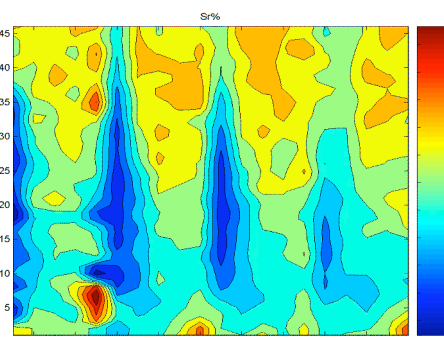
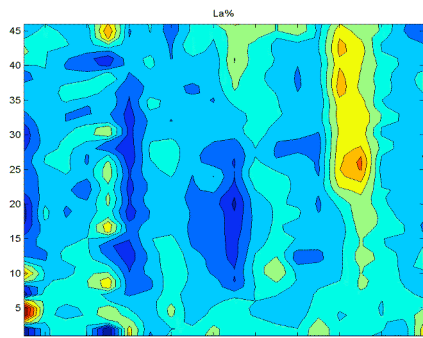
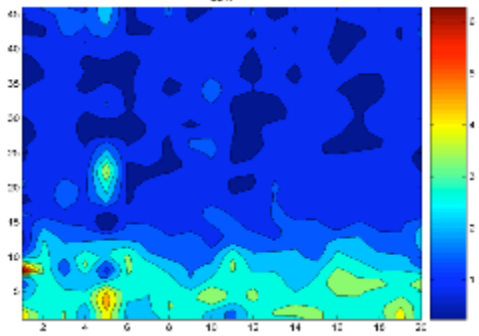
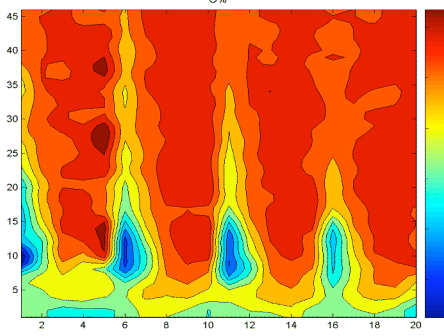
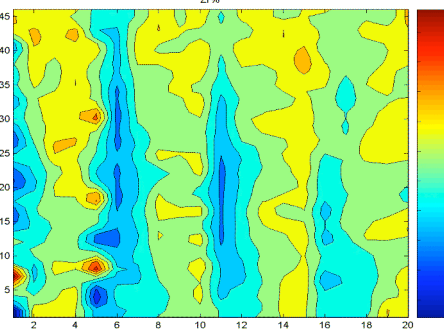
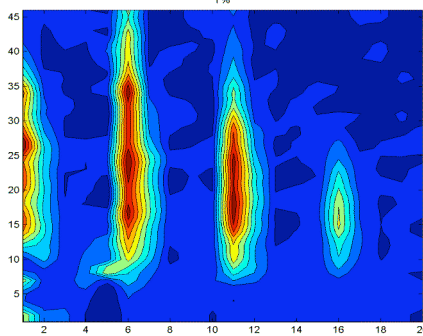
# LEAP study

Y

Zr

O

Ga



La

Sr

Co

Fe

UF-DOE HiTEC



UNIVERSITY of  
**FLORIDA**  
*ation for The Gator Nation*



A 21<sup>st</sup> Century Approach to Reliability

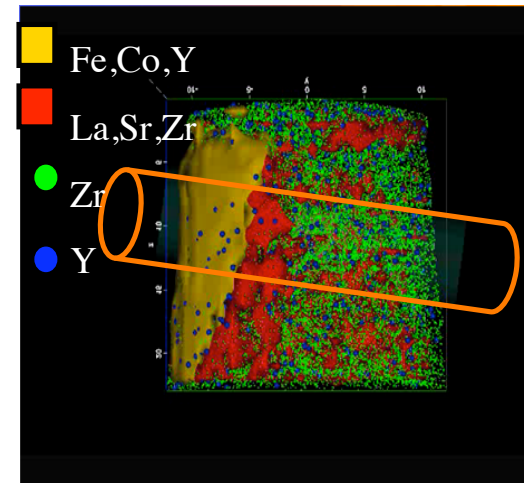
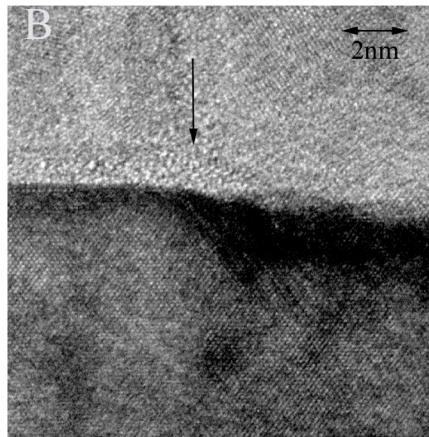
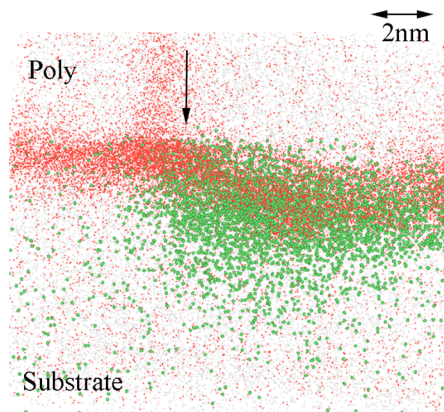




# Conclusions

LEAP-TEM  $\Rightarrow$  chemical-morphological

- Atomic level resolution
- well tested on Si device
- Promising to characterize failure of SOFC devices



# Acknowledgements

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Swamp Center:  
Sam Moore,  
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Sidan Jin,  
Ray Holzworth

